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The Development of Working Memory: Further Note on the Comparability of Two Models of Working Memory

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This paper is a set of reflections on Kemps, De Rammelaere, and Desmet's article (2000, this issue), in which the two models by Baddeley and Pascual-Leone are compared. First, some of the similarities and differences between the two models which we identified in a 1994 paper (de Ribaupierre & Bailleux, 1994) are briefly summarized and reexamined in the light of more recent work. Second, we debate the issue of whether each model makes a specific contribution to the explanation of some of Kemps et al.'s results, that is, of whether they can be considered to be complementary. Third, we argue for the necessity of theoretical task analyses, in view of the divergent results obtained in the two tasks used (the Corsi and the Peanut tasks), notably different developmental profiles, and an overall higher level of performance in the Corsi task. Finally, we briefly summarize a very similar study in which we also used Mr. Peanut with concurrent tasks in children and in young adults and in which we obtained rather different results. By comparing the experimental procedures used in the two studies, we contribute some exploratory hypotheses, while raising issues that can easily be generalized to other visuo-spatial working memory tasks.

Key Words: working memory; visuo-spatial working memory; cognitive development; neo-Piagetian; Baddeley's model; dual tasks.

We would first like to acknowledge with appreciation the opportunity afforded by this forum to clarify and develop some of the arguments we presented a number of years ago (de Ribaupierre & Bailleux, 1994). We were pleased that

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Kemps, De Rammelaere, and Desmet (2000, this issue) found our earlier work useful as a starting point to devise an informative experimental study for further exploring the possible complementarity of Baddeley's and Pascual-Leone's models of working memory.

In conformity with the format of *JECP Reflections,* we consider some theoretical, analytical, and empirical issues raised by Kemps et al.'s article. Our paper addresses four general themes. First, we reiterate, and reexamine in the light of more recent work, some of the similarities and differences between the two models which we identified in 1994, and which were briefly summarized in the lead paper. Second, we comment about Kemps et al.'s objective and ask whether the study in fact demonstrates the complementarity of the two models under discussion. This leads us to distinguish between non-incompatibility, on the one hand, and complementarity of theories, on the other hand. Third, we focus on some results presented in the lead paper, and more specifically on the difference between the two tasks which were used, that is, between the Peanut and the Corsi tasks. The developmental courses of these two tasks appear to be very different, when only the number of correctly retrieved positions is considered, and performance seems to be higher in the Corsi task. We argue that more elaborate task analyses are needed in place of merely comparing number of correct responses; we speculate about how information may be encoded and chunked in each of the two tasks, and we discuss these differences in the light of recent research in the field of visuo-spatial working memory. Finally, we compare the results presented in the lead paper with those we obtained in a very similar study (which is very briefly summarized), in which we also used Mr. Peanut with concurrent tasks in children and in young adults. In contrast with Kemps et al.'s results, children as old as 8 and 10 years of age apparently still relied almost exclusively on a visuo-spatial mode of encoding, and were not hampered by a concurrent verbal suppression task. Although we do not understand why results are so divergent, we will nevertheless attempt to contribute some exploratory hypotheses.

ON THE COMPATIBILITY OF BADDELEY'S AND PASCUAL-LEONE'S MODELS

At first glance, Baddeley's model of working memory and neo-Piagetian models, in particular Pascual-Leone's theory, appear very different, if not irreconcilable. In our 1994 paper, we argued that the two are closer than it first appears, even though they have tended to largely ignore each other. Building a bridge between the two traditions that these models represent, namely an adult experimental and a broad developmental perspective, appears interesting from a general, epistemological perspective. It is only by combining different traditions of research that a more integrative picture of cognitive functioning will ultimately be obtained. In particular, we have argued (e.g., de Ribaupierre & Pascual-Leone, 1984) that adult cognitive functioning will be fully understood only when its development is also taken into account. Obviously such a claim is in conformity with Piaget's position that a structure cannot be dissociated from its genesis (e.g., Piaget, 1968). Whether development takes a continuous or a discontinuous form, adult cognitive functioning should be envisaged as an objective toward which development leads (without necessarily adopting a finalist position). From a life-span developmental perspective, too, there exist a few general processes which are at work throughout the life span (e.g., Baltes, Lindenberger, & Staudinger, 1998; Baltes, Reese, & Lipsitt, 1980) and should account not only for changes with age, but also for cognitive functioning in specific situations at a given point in time. This does not deny that specific processes may take place and have more importance at some times and situations than at others, perhaps even overruling general processes. This is precisely where models such as Baddeley's and Pascual-Leone's could show best their complementarity. Baddeley's experimental approach has essentially focused on the different processes at work within a single class of paradigms, and on the predictive power of these paradigms for other, relatively similar situations. Relationships between working memory and cognitive performance at large have been studied, but no developmental predictions have been formulated. In contrast, Pascual-Leone's model has provided broad hypotheses, relative to general mechanisms at work in a whole range of cognitive situations, and is able to account for developmental change as well as for individual differences.

From a less general perspective, we tried showing earlier (de Ribaupierre & Bailleux, 1994) that the two models addressed similar issues and that they could account, at least partly, for the same empirical phenomena. We do not want to fully develop again here the similarities and differences we identified then with respect to their approach to working memory, especially as Kemps et al. summarized most of our arguments; we will just sketch the most important ones. First, we stressed the fact that both models were multidimensional; that is, they both consider that working memory is not unitary. This is obvious with respect to Baddeley's model, which defines working memory as composed of several, relatively independent subsystems (e.g., Baddeley, 1986; Baddeley & Logie, 1999). Pascual-Leone's model has often been understood as if it were assuming a unitary system to account for the development of working memory; this is because most analysts (e.g., Baddeley, 1986) focused only on the growth with age in M-power postulated by Pascual-Leone. On the contrary, the model is fundamentally multidimensional, because it postulates several, independent underlying mechanisms (such as the M-, I-, or F-operators—see Pascual-Leone, 1987, 1989) whose function is to activate informational schemes or units. Moreover, Pascual-Leone has explicitly defined different types of representational formats, such as infralogical (retaining spatiotemporal and/or causal properties), logological (generic knowledge), and linguistic (verbal). It should be stressed, furthermore, that Pascual-Leone's multidimensional model offers explicitly the possibility of accounting for both situational and individual differences: The relative weights of the operators may vary across situations as well as across subjects (e.g., Pascual-Leone, 1987; de Ribaupierre, 1983). In contrast, the different subsystems of Baddeley's model have thus far only been associated with various types of experimental situations, although they could certainly also be tied to individual differences (e.g., de Ribaupierre, 1995).

A second obvious similarity of the two models is the emphasis placed on executive processes. Baddeley's model postulates the existence of an attentional controller, the central executive, whose functions have recently been more explicitly formulated (Baddeley, 1996). This concept has been dealt with at two levels, and with much greater theoretical precision, in Pascual-Leone's model (Pascual-Leone, Goodman, Ammon, & Subelman, 1978; de Ribaupierre, 1983). At one level, Pascual-Leone has proposed distinguishing between figurative, operative, and executive schemes, the last being in charge of allotting resources, selecting relevant features of the information to be processed, planning mental actions, and monitoring processing. At another, "deeper" level, the construct of the "field of mental attention" refers to the "silent operators" that are at work in tasks requiring effortful processing. Mental attention is here defined as consisting of three mechanisms: (1) The M-operator serves to boost task-relevant schemes not directly activated by the display or by other mechanisms. M-capacity or M-power is a limited resource that increases up to adolescence, in a stagewise manner. (2) An inhibition mechanism, the I-operator, is responsible for actively inhibiting or interrupting less relevant or irrelevant schemes. This operator is crucial in the management of attention, ensuring that schemes activated by M become dominant and determine performance. (3) The F-operator is considered to be important for the selection of action in attentional processing, and its function is to produce a single integrated whole, by activating the set of schemes that is both minimally complex and maximally adaptive. The field of mental attention consists of those informational units which are very highly activated (or deactivated as concerns the I-operator) by these three mechanisms, acting in conjunction with executive schemes.

There are other points of similarity and convergence between the two models, in particular with respect to the predictions which they can offer for a number of empirical phenomena, such as the possibility of interference between two tasks in a dual task paradigm. Thus, in our 1994 paper, we attempted to show that both models could account for an intriguing empirical result obtained in a longitudinal study on working memory, namely the fact that the computerization of a visuo-spatial task led to a drop in performance from one year to the next, which we interpreted in terms of interference.

The concept of interference is indeed granted an important role in both models, although at a very different level. Baddeley relied on the presence (or the absence) of interference, as empirically indexed by a decrease in performance, to suggest the independence of the working memory subsystems (e.g., Baddeley, 1986). He showed that, when two verbal tasks (such as remembering a series of digits and judging sentences) had to be performed simultaneously, there was a decrease in performance, attesting to the fact that the two tasks were drawing upon common resources. When the same verbal task had to be performed with a visuo-spatial one, performance remained more or less invariant. A reciprocal pattern was observed with respect to visuo-spatial tasks. It was therefore concluded that there are at least two independent subsystems, notably the phonological loop and the visuo-spatial sketchpad. Likewise, Kemps et al., in the lead paper, relied on the drop in performance which was observed when the Peanut task had to be performed with a spatial suppression task to infer that the task is processed by a visuo-spatial mode.

In contrast, Pascual-Leone's model was not built on the empirical observation of phenomena of interference, but it can nevertheless account for such effects, at different levels. First, and perhaps most trivially, interference can be predicted when two tasks are difficult enough to require the contribution of the M-operator and when their combined demand exceeds the subject's M-capacity. Second, if two tasks call for the same type of schemes (such as two tasks calling for infralogical schemes), interference is likely to emerge, for the same reasons as those invoked by Baddeley. Third, and most importantly, the distinction introduced by Pascual-Leone between facilitating and misleading tasks has been central in the theory since its very beginning (e.g., Pascual-Leone, 1969). Misleading situations are those in which different silent operators activate incompatible sets of schemes, one of which is often more highly activated while leading to an incorrect solution. In contrast, in facilitating situations, different sets of schemes are activated which all concur to a correct solution. Good examples of misleading tasks are the Piagetian conservation tasks, in which a perceptual dimension is highly activated and competes with a correct response based on invariance. For example, in the conservation of substance task, a ball of plasticine is transformed into a sausage, and the change in length may lead the child to believe that the quantity has increased (or decreased when considering the change in thickness). The correct solution in a misleading task requires interruption of the irrelevant schemes and strong activation by M of both the relevant schemes and the executive schemes, thus depleting the total pool of resources available. For instance, when the Peanut task is administered in a dual condition in Kemps et al.'s study (e.g., concurrently with a spatial task), the movement required by the secondary task may be incompatible with the encoding of positions in the Peanut task and may have to be inhibited by the I-operator. Moreover, it may also be the case that each position to be remembered necessitates a supplementary activation by M, relative to the single condition. As a result, more attentional resources (i.e., M- and I-operators) are used, explaining why performances are lower than in the single condition.

Even though there exist points of similarity and convergence between the two models, as we just attempted to show, there remain also some profound divergences, in addition to the epistemological difference discussed earlier. In particular, the definition of working memory is very different. Baddeley's model clearly belongs to the tradition which considers working memory as a "memory system" in the sense of constituting a distinct structural component (e.g., Schacter & Tulving, 1994). Just as clearly, Pascual-Leone's model belongs to the alternative tradition, which suggests that working memory only designates either an activated subset of long-term memory (e.g., Cowan, 1995, 1999; Ericsson & Kintsch, 1995) or a set of processes at work in working memory *tasks* (e.g., Moscovitch, 1992). This definition of working memory is best represented in the North American tradition of research, which is concerned with individual differences in the capacity of working memory and with their predictive power with respect to other cognitive tasks (e.g., Engle, Kane, & Tuholski, 1999), or in some neuropsychological approaches which consider that working memory tasks call for both activation and inhibition (Cohen, Braver, & OReilly, 1996; Pennington, 1994; Roberts & Pennington, 1996). Within this tradition, there is no need to distinguish processes specific to working memory from processes at work in other cognitive tasks. Working memory only corresponds to a particular type of tasks; such tasks are very close to short-term memory tasks, but may ask for some type of supplementary processing to ensure that attentional or controlled processing is engaged (e.g., de Ribaupierre, 2000). The accent is placed on the amount, rather than on the nature, of information which is processed, and working memory tasks are used to assess the limits in the resources available for such processing.

The distinction introduced by Pascual-Leone between the "field of working memory," referring to schemes activated both by the stimulus and by most silent operators (Pascual-Leone & Ijaz, 1989), and the "field of mental attention" (subset of working memory, consisting of schemes highly activated by M, I, F, and E—see above) should contribute to specifying more precisely what working memory tasks actually measure. It is to be stressed, however, that the more recent theorization of the central executive by Baddeley (1996) contributes to narrowing the gap between these two traditions of working memory research. Thus, Richardson (1996a, 1996b) offered a very constructive summary of the different approaches and suggested, among other propositions, that it is now consensual to consider that the capacity of working memory is constrained by limitations in the amount of activation that can be distributed and by limited attentional resources available to activate and maintain task-relevant information while inhibiting task-irrelevant information.

ABOUT KEMPS ET AL.'S STUDY AND THE COMPLEMENTARITY OF THE TWO MODELS

Whereas we presented our hypotheses in 1994 as essentially illustrative because they were developed *a posteriori* on the basis of already-obtained results, Kemps et al. take it as an objective to test the complementarity of the two models. They used two visuo-spatial tasks, a unicolored version of the Peanut task (a task adapted from Pascual-Leone and Case, in which a clown figure is presented with colored dots in a number of body parts, and positions of these colored dots have to be remembered in a free recall paradigm) and the Corsi Blocks task (a display with nine blocks, of which a particular sequence of blocks has to be recalled in the same order). Both tasks were presented to 5-, 6-, 8-, and 9-year-olds. They were administered with or without a very simple concurrent task, spatial or verbal, in line with the suggestion we made in our 1994 paper to use a dual task paradigm to understand better the processes at work in the Peanut task. Results showed that the younger children were hampered only by the visuo-spatial concurrent task (continuous tapping task), whereas older children, but particularly 8-year-olds, were hindered by both concurrent tasks.

This type of dual task paradigm is widely used in working memory studies (as well as in other fields) as a way to study the processes used for encoding, maintaining, or retrieving information. The principle is that if a given process is used in the primary task, it should be interfered with when a secondary task also relies on that same process. Halford (1993), for instance, discussed some difficulties linked with this method, the most obvious being that having to perform two tasks simultaneously increases the complexity of the task altogether; it is also very difficult to ensure that the secondary tasks are of equal complexity. As a consequence, the decrease in performance which is observed in the primary task in the dual condition relative to the single condition may result from this increase of complexity rather than from interference with a particular process. Nevertheless, the dual task paradigm has shown a number of interesting phenomena. Kemps et al. thus showed that young children, when they have to perform a visuo-spatial task, are much more interfered with by a concurrent visuo-spatial task than by a verbal one, even though the information to be remembered could be verbally encoded and maintained. These results, using a different task, were thus in conformity with the work of Hitch and collaborators, who suggested that young children seem to rely essentially on visual coding, whereas older children can also rely on phonological, or more generally, verbal coding.

However, although interesting per se, such results do not address the issue of the complementarity of the two models. Incidentally, the authors mention that the complementarity of two models is both a theoretical and an empirical matter, and specify that their study addresses empirical complementarity. They seem to imply, in contrast, that our paper was addressing theoretical complementarity. A clarification is in order, here. The main objective of our paper was not so much to argue for the complementarity of Baddeley's and Pascual-Leone's models—although we indeed used this term—but rather to attempt to show that the two were not as different as might appear at face value, and thus that an integration was possible. We argued that both models could account for the same phenomena, albeit Pascual-Leone's model somewhat more generally, and Baddeley's model perhaps with more precision with respect to a much more restricted phenomenon. Therefore, we should probably have emphasized much more the *convergence* or the compatibility of the two models rather than their complementarity.

The question remains, however, of whether Kemps et al.'s study indeed demonstrates the complementarity of the two models. If the two models were complementary, from an empirical point of view, they should each make a specific contribution, which, together, would account better for the results than could either model alone. In the present case, both models predict that a visuo-spatial concurrent task will interfere with young children's performance on the Peanut task. However, neither model can predict precisely the magnitude and, most importantly, the change with age in the nature of interference.

According to Baddeley's model, the interference is due to the fact that both tasks (such as the Peanut task and the spatial tapping task used in the lead paper) are processed by the visuo-spatial sketchpad. More exactly, according to the logic underlying the use of a dual paradigm, the decrease in performance observed in the Peanut task when a visuo-spatial concurrent task is administered leads to the conclusion that the task is processed by the visuo-spatial sketchpad. Likewise, the fact that young children show the most interference from the visuospatial concurrent task and that older children are hampered by the verbal concurrent task as well shows that the modes of encoding change with age. This finding conforms with previous findings by Hitch and collaborators (Halliday & Hitch, 1988; Hitch, Halliday, Schaafstal, & Schraagen, 1988; Hitch, Woodin, & Baker, 1989), and could have been predicted on this basis (indeed, it was predicted). However, it is in no case an intrinsic characteristic of Baddeley's model. Rather it is a prediction based upon previous empirical work, most of which was indeed conducted within Baddeley's perspective.

As was discussed in the first section of this *Reflection*, Pascual-Leone's model can also account for interference effects, not only because performing the tasks concurrently probably represents a heavier processing load (increase in complexity), but also because the two tasks may call for the same modality of processing. Because the I-operator must then contribute more actively, more attentional resources are required and performance may be lower. The notion that modes of encoding, or strategies, change with age is also totally compatible with a developmental theory that postulates not only an increase in the resources with age, but an enlargement of the knowledge base and an increasing sophistication of executive schemes (Pascual-Leone & Goodman, 1979). Such developmental change may indeed explain why several modes of encoding become available simultaneously. In that sense, one can consider that an increasing use of the verbal mode (that is of a mode which is less readily available, or data-driven, in the Peanut task) could have been predicted, on theoretical grounds, by Pascual-Leone's model. The theory is not, however, precise enough to predict that children will indeed change encoding modality around 8 or 9 years of age.

Another argument presented by Kemps et al. in favor of the complementarity of the two models is apparently linked to the origin of the tasks. Thus, the Peanut task was developed within the neo-Piagetian tradition, and Baddeley's model can be used to analyze the results. Reciprocally, Pascual-Leone's model can be used to make some developmental predictions with respect to the Corsi task, which developed within a different theoretical tradition. This is not to be considered as complementarity, however. Indeed, there is no reason to consider a particular association between a task and a theory. Even though the Peanut task was primarily used within the neo-Piagetian tradition, because task analyses showed it to be potentially interesting to provide a relatively "pure" measure of M-capacity (Case, 1985; de Ribaupierre, Neirynck, & Spira, 1989), it is by no means intrinsically neo-Piagetian (see also de Ribaupierre, Lecerf, & Bailleux, 2000). Likewise, the Corsi task (which incidentally was not developed within the Baddeley tradition but rather as a neuropsychological tool; cf. Milner, 1971) could have been used by neo-Piagetians. Indeed, spatial sequential span tasks were used by Case and collaborators (e.g., Case, 1992).

In summary, what remains of the specific contributions of each model? Both models predict interference from a concurrent visuo-spatial task, for slightly different reasons; they can also account for change in the nature of encoding with age, although we mentioned above that Baddeley's model cannot explain this change on theoretical grounds and that Pascual-Leone's model was somewhat too general to predict the age at which this change would take place. The contribution of each model is therefore partly overlapping and reflects more of a convergence or of a compatibility than a true complementarity. We would like to argue, however, that Pascual-Leone's model makes an additional contribution, by predicting a specific developmental course. A very nice feature of Kemps et al.'s study was to select age groups which, although equally spaced in chronological age, were predicted to present different performances, in conformity with Pascual-Leone's stagelike model. Thus it was predicted that the 5- and 6-year-olds should behave at an equivalent level, whereas the 9-year-olds should be superior to the 8-year-olds, despite the 1-year difference in age in both cases. This pattern was indeed observed in the Peanut task, but not in the Corsi task, showing clearly that more analyses have to be conducted.

ON THE NECESSITY OF TASK ANALYSES

The authors' predictions were identical for both tasks, except with respect to the influence of the concurrent task. In terms of developmental change, a stepwise development was expected, with an increment of one unit every 2 years. Given the age groups selected, it was predicted that 5- and 6-year-olds should present the same level of performance because they are considered by Pascual-Leone's theory to belong to the same M-stage, whereas 8- and 9-year-olds should differ by one unit. In contrast, the authors' hypothesis was that the Peanut task can be both verbally (because the positions can be labeled) and visuo-spatially encoded, whereas the Corsi task should be a more pure visuo-spatial task. Moreover, Hitch et al.'s (1988) studies demonstrated a progressive complementation of visuo-spatial coding by a verbal one, starting around 10 years of age. As a result, Kemps et al. expected that a concurrent spatial task would introduce an effect of interference in both the Peanut and the Corsi tasks, while a verbal concurrent task would have an effect only in the Peanut task, and possibly only in the older children. Results did not totally conform to these two sets of predictions. With respect to the developmental prediction, the Peanut task behaved as expected, but the Corsi task did not. Indeed, in the latter task, 9-year-olds were not better than 8-year-olds. Moreover, although apparently not significantly so, 6-year-olds appeared to be somewhat better than 5-year-olds. With respect to the differential effect that the concurrent tasks were expected to exert on the two tasks, results globally conformed to the hypotheses: The verbal suppression task had no effect in the Corsi task, but had an effect for the 8- and 9-year-olds in the Peanut task, whereas the spatial suppression task had an effect in both tasks and in all age groups. It should be noted, however, that spatial suppression had a stronger effect on the 9-year-olds than on the 8-year-olds in the Peanut task, whereas, based on Hitch et al.'s hypothesis of a progressive complementation, the reverse should have been observed. We will discuss this point again in the next section. Finally, the authors point to another result, which they consider as surprising, namely the fact that performances were altogether much higher in the Corsi task.

Relatively large differences were thus observed between the Corsi and the Peanut tasks, only some of which were predicted. The overall difference in performance is of particular interest to us, and points to the necessity of thorough task analyses. According to Kemps et al., this is all the more intriguing as the Corsi task requires serial recall whereas the Peanut task requires free recall and free recall is usually associated with better performances. They advanced three interpretive hypotheses to account for these unexpected results, all of which point to the necessity of detailed, and if possible a priori, theoretical task analyses.

First, Kemps et al. point to the number of locations to be remembered, which is higher in the Peanut task than in the Corsi task, and to the fact that positions are embedded within a much larger amount of information in the former task. As a result, children may be "overwhelmed by the amount of information presented at the same time" (Kemps et al., 2000, p. 101). Second, a sequence of movements is constructed step by step in the Corsi task, possibly guiding the children to concentrate on one block at a time. Third, the different body parts may be semantically encoded in the Peanut task, evoking associations that may have to be inhibited to successfully perform the task.

Although we agree with most of these interpretations, we argue that they are not sufficient to account for the differences observed, and that they should be developed further. Moreover, the third hypothesis raises additional questions. On the one hand, one could just as well argue that the possibility of semantically encoding the positions in the Peanut task should enhance performance, rather than reduce it. Provided the information to be encoded (name of the body part and spatial position) is not contradictory, dual coding (Paivio, 1971) should lead to more thorough encoding and better retrieval. On the other hand, if one were to nevertheless adopt the authors' hypothesis according to which semantic information has to be inhibited, then results should be different in young children. Because young children are not supposed to encode visuo-spatial information verbally, they should not need to inhibit the names of the positions and should therefore present identical performance in the two tasks; this was not the case.

Therefore, additional explanations must be found to account for the difference in the number of positions retrieved. We would like to offer at least two supplementary speculations that do not contradict Kemps et al.'s hypotheses, but are complementary in the sense that they perhaps spell out more explicitly earlier ones. First, the Peanut task is probably more of a misleading task, in the sense defined above—or at least a distracting task (Pascual-Leone, 1969)—than is the Corsi task. The relevant information has to be extracted from a large amount of irrelevant information in the Peanut task. That is, the positions to be remembered in a particular trial have to be distinguished from other body parts which either were relevant in previous trials or are not central in the task because they never have to be remembered (e.g., the hands, or the belly of the clown), while belonging to the same meaningful, overall figure. This is probably the point that Kemps et al. want to stress when they mention a large amount of information within which the positions to be remembered are embedded. Yet, the distinction between misleading and/or distracting tasks on the one hand, and facilitating tasks, on the other hand, is theoretically more precise, all the more so as Pascual-Leone has emphasized that misleading tasks require more attentional processing. In this sense, the Corsi task is easier, because it contains less information and because the relevant positions to be remembered in a given trial are pointed out by the experimenter. The latter could even constitute a facilitating feature.

Second, we would like to argue that it is easier to encode larger chunks of information in the Corsi task than in the Peanut task, because paths can be created, and are even facilitated by the experimenter's movement. We argued elsewhere (Lecerf, 1998; de Ribaupierre et al., 2000) that visuo-spatial encoding of positions in tasks such as the Peanut task may take three forms that can be combined: extrafigural encoding of spatial coordinates (i.e., encoding each position relative to a general frame of reference), intrafigural encoding under the form of visuo-spatial or visual patterns, and intrafigural encoding under the form of paths, that is, of dynamic links between the different positions. Whereas extrafigural encoding leads to each position being processed and possibly maintained separately from each other, the latter two modes of encoding should make it possible to process larger chunks of information, and should therefore lead to higher performance. The possibility of combining these different modes depends partly on the experimental procedure used. In a simultaneous presentation (such as pattern span tasks—e.g., Logie, 1995; Logie & Pearson, 1997; Wilson, Scott, & Power, 1987), in which all the information to be encoded is presented at the same time, the three modes can in principle be used. In a sequential presentation (such as spatial span tasks, in which positions are presented one at a time), only the extrafigural and the path encoding modes are likely; the creation of a visuo-spatial pattern (global or partial image containing several positions) is more difficult, if not impossible. Thus both intrafigural modes (i.e., visual patterns or images and paths) should be possible in the Peanut task because all the information is presented simultaneously. However, because the positions are interspersed among other irrelevant information, it is probably relatively difficult to build patterns or paths. In contrast, in the Corsi task, paths are relatively easy to make, and are made all the more salient by the experimenter's movement. Although the creation of a pattern is difficult because of the sequential presentation, paths should be sufficient to help pack more than one position in a single chunk. Therefore, performance should be higher than in the Peanut task.

The distinction between visuo-spatial patterns and paths is congruent with recent work. It is, in particular, akin to the distinction introduced by Logie (1995) between the visual cache and the inner scribe. The visual cache would be used in pattern tasks whereas the inner scribe would be required in spatial span tasks. Thus, both modules could be used in the Peanut task, but with the difficulties just mentioned. The inner scribe could easily be used in the Corsi task, thus accounting for the fact that a concurrent spatial task has more effect in this task. It is worth noting that Logie and Pearson (1997), as also mentioned by Kemps et al., suggested that the two types of memory tasks may be subject to "developmental fractionation," that is, would undergo different developmental courses. In this respect, we would like to suggest that an analysis conducted in terms of chunks rather than merely the number of positions retrieved could lead to different conclusions. It may be the case that the difference in developmental rate observed by Logie and Pearson only reflects the fact that more positions can be packed in a single chunk in the pattern task than in the spatial span. As a result, development would appear faster in the former than in the latter task, even though the increase in the number of chunks could be identical in both tasks.

ON THE DIVERGENCE OF RESULTS BETWEEN KEMPS ET AL. AND DE RIBAUPIERRE ET AL.

As we mentioned in the Introduction, a somewhat similar set of studies was conducted a few years ago in our own laboratory and led to partly divergent results (de Ribaupierre et al., 2000). The Peanut task was administered in two versions, a unicolored version like the task used by Kemps et al. and a multicolored one in which positions and colors had to be remembered, to children aged 6, 8, and 10 years (Study 1) and to young adults (Study 2), together with a concurrent verbal task (phoneme repetition) or a visuo-spatial task (tracking a Z-like figure). In the case of young adults, an additional experimental manipulation was used and the Peanut task was administered under a simultaneous versus a sequential presentation. Results were very straightforward. In children, the concurrent verbal task had no significant effect, relative to a control condition in which the Peanut task was administered without a concurrent task, whereas the spatial concurrent task led to lower performance than both the verbal and the control ones. Moreover, there was no condition by age interaction, implying that the concurrent tasks had the same effect in the three age groups. It should be stressed that, in the colored version (i.e., in a task different from that used by Kemps et al.), the verbal concurrent task exerted, as expected, a slight effect on the recall of colors but not on the recall of positions. In contrast, only the verbal concurrent task had an effect in adults, and there was just no effect of the spatial concurrent task. Furthermore, for young adults, it proved necessary to modify the Peanut task itself to observe an effect of the spatial concurrent task (Study 3). The outline of the figure was suppressed (and the task labeled Ghost-Peanut), and there remained only a display of circles which appeared rather randomly arranged, but was actually identical to the initial Peanut display. The objective of this modification was to minimize, if not totally suppress, the possibility of verbally encoding the positions. As a result, the concurrent spatial task finally had an impact on the recall of positions, whereas the verbal suppression task still influenced the recall of colors; it is interesting to stress that, despite the fact that the verbal coding was made more difficult, recall was not lower in this modified task. It was then concluded that children as late as 10 years of age relied almost exclusively on visuo-spatial encoding, whereas adults massively resorted to verbal encoding unless it was no longer possible.

How is it possible to explain such a divergence in results? There were several differences between the experimental procedures that preclude a full comparison of results. First, Kemps et al. used a span procedure (i.e., presenting the stimuli in increasingly longer sequences with three trials for each length, and stopping testing when two or more trials of a given length were failed), whereas we used the same task for almost all age groups (6-year-olds had a slightly easier task), with trials of different length randomly distributed across the task. To our knowledge, there are no studies that have assessed whether these two types of administration yield different results; however, Mukunda and Hall (1992) consider that administering the same number of trials at each span length for all subjects increases the quality of memory for order tasks because they increase their reliability.

Second, Kemps et al. used a within-subject design whereas we used a between-subject design. More precisely, all the subjects in our study were administered the task twice, first without a concurrent task and then in a dual condition (except the control group, who were administered the task twice in a single condition). Once again, it is difficult to assess whether this can account for the divergence. Nonetheless, in all our studies in which the Peanut task was administered several times to the same subjects, including a longitudinal study (de Ribaupierre &

Bailleux, 1991, 1994, 1995; de Ribaupierre, Bailleux, Lecerf, & Thomas, 1992), practice effects were observed. This is the reason that we compared performance across experimental groups on the second assessment, controlling for the performance on the first assessment and thus ensuring that all subjects were thoroughly familiar with the task. Analyses were, however, also run on the two assessments, comparing for each experimental group the Peanut task in a single versus a dual condition. These analyses yielded the same results: In children, only the spatial task showed a significant effect, and condition did not interact with age. Kemps et al. used a full within-subject design in which all experimental conditions were administered to all subjects, in a counterbalanced order; therefore, there is a possibility, given the small number of subjects by age group, that experimental effects were confounded with practice effects.

Third, we used two versions of the Peanut task (however, all subjects had the unicolored Peanut task first). This allowed us to conclude that the concurrent tasks had a specific effect: Recall of positions seemed more sensitive to a spatial concurrent task, whereas recall of colors was influenced by the verbal concurrent task. Another interesting experimental manipulation which we introduced in the adults was to contrast a sequential versus a simultaneous presentation. Our results showed that a sequential presentation was more difficult, probably both because subjects cannot group several positions within a single chunk and because the allocation of attention is more constrained. In contrast, in a simultaneous presentation, one can scan several times the same positions, and encode them in any order (see also Lecerf, 1998).

Of course, a trivial interpretation could be that the divergence between Kemps et al.'s results and ours is due to a low reliability of the data, in either study. In preceding studies in which we used the Peanut task, we usually obtained test–retest coefficients around the 80s, independent of age, except in 5-year olds, where coefficients were somewhat lower. In any case, a replication of the experiment is needed before more definitive conclusions can be reached. However, we would like to argue that an additional, more interesting hypothesis should be considered, related to the issue of individual differences. Another intriguing result in Kemps et al.'s study was indeed the fact that the spatial suppression had more effect in 9-year-olds than in 8-year-olds, relative to the verbal one; the reverse would have been expected, as a verbal code appears to become progressively dominant over a spatial one with age (e.g., Hitch et al., 1988). Moreover, under spatial condition, the two age groups were apparently not different. Of course, it is difficult to compare the effects directly without knowing the effect sizes. Nevertheless, one can wonder whether the 9-year-olds were particularly sensitive to spatial interference, or whether 8-year-olds were particularly prone to verbal interference. Of course, the latter possibility would allow the reconciliation of the two sets of results. It could be the case that a majority of 8- and 9-year-old children still rely on spatial encoding and that few children resort to verbal encoding, but so strongly that a significant group effect is obtained. Thus, it would be worth assessing whether all individuals conform to the observed effect, which is obviously possible only when a within-subject design is used. All too often, one takes for granted, even if only implicitly, that a robust experimental effect, observed at the group level, is necessarily present in all individuals. However, this assumption is probably unwarranted. For instance, Della Sala et al. (Della Sala, Logie, Marchetti, & Wynn, 1991; Logie, Della Sala, Laiacona, Chalmers, & Wynn, 1996) showed that, despite a very strong effect of word length on verbal recall—a well-known and very robust effect in working memory studies—almost 25% of the subjects did not present it. In our study, it was observed that, even though only the spatial concurrent task had a significant effect in children, there were nevertheless a number of children who were affected by the verbal concurrent task. For each of the age groups 6, 8, and 10 years, there were, respectively, 50%, 75%, and 67% of the sample who presented lower performance on the second assessment (verbal concurrent task) than on the first one, versus 75%, 83%, and 75%, respectively, in the spatial condition. Interestingly, in the spatial condition, respectively 17%, 17%, and 25% had higher performance in the spatial condition despite the significant effect of this condition. Likewise, in adults where it was observed that only the verbal concurrent task had an effect, there were nevertheless 31% of the subjects who showed lower performance in the spatial task than in the control one; reciprocally, 40% of the subjects presented higher performance in the verbal condition relative to the control one. These data are only indicative and descriptive, all the more so as the significance of the within-subject differences was not tested. Yet, it would certainly be interesting to conduct such analyses on the Kemps et al. data.

The hypothesis that there exist not only quantitative but also qualitative individual differences (i.e., differences in the nature of encoding) in this type of task appears particularly worth pursuing, as we already suggested elsewhere (de Ribaupierre, 1995). A task like the Peanut task appears promising from this point of view because of the possibility it offers of dual coding, visuo-spatial and verbal. It could be the case that some individuals prefer one mode, whereas others prefer another mode. Unfortunately, so far, we have not been able to evaluate this hypothesis empirically. Verbal encoding seems so important in adults, at least in this task, that it tends to preclude the possibility of individual differences emerging. Perhaps the modified Peanut task mentioned above (the Ghost-Peanut task) would be more amenable to showing different encoding modes in different subjects. More generally, we would like to argue not only that there are developmental changes in the relative importance of encoding modes, as was shown by Hitch et al.'s studies as well as in the lead paper discussed here, but also that individuals may differ in terms of the mode they prefer using, at least when the situation offers a choice and when several modes are available. A way to test this hypothesis empirically could consist in forming groups of subjects on the basis of other variables such as verbal and spatial abilities (psychometrically defined), cognitive style (field-dependence-independence), and/or sensibility to irrelevant information, and assessing whether these groups react differently to a verbal or to a spatial, concurrent task. Integrating a differential perspective within studies on working memory would of course present the advantage of building yet another bridge between traditions in cognitive psychology, namely between the psychometric and the experimentalist approaches of adult cognitive functioning tasks (see also MacLeod, Hunt, & Mathews, 1978).

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